

The Processing of Pitch and Scale: An ERP Study of Musicians Trained Outside of the Western Musical System

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ABSTRACT: The current study extends the efforts of Bischoff Renninger, Granot and Donchin (2003) to non-Western musical systems and focuses specifically on Event-Related Potential (ERP) responses to scalar deviations within the Javanese pélog scale by groups of musicians trained within the Western and Javanese systems. The principal aim is to ascertain whether results found in previous experiments may be obtained cross-culturally. Participants include five subjects trained in the Western system only (control group) and five subjects trained in both the Western and Javanese systems (experimental group). Tasks include identifying scalar deviations within the Western diatonic scale, identifying scalar deviations within the Javanese pélog scale, and identifying target letters in a visual control task. ERP and overt behavioral responses are recorded. Results show significant differences between group responses to diatonic and Javanese scale conditions. Interesting results also arise in terms of how tones and intervals in the different scales are conceptualized by subjects in both groups. Control subjects especially tend to assimilate pélog scale intervals to intervals in the Western equal-tempered scale.

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KEYWORDS: *music, scale, ERP, event-related potential, tuning, interval, enculturation*

INTRODUCTION

IN human culture, music is as far-reaching a phenomenon as language. And, like language, learning another culture's music can be both complicated and challenging. Even so, researchers have documented various musical elements (i.e. the division of the octave into discrete rather than continuous pitch levels, the use of 5-7 pitches per scale, the hierarchical arrangement of pitches within the scale) that appear to be shared among various cultures (Dowling & Harwood, 1986). In the current study we were very interested to know if there were also cross-cultural similarities in music cognition. The vast majority of music cognition studies focuses on Western music and tends to disregard other musical systems. According to Dowling and Harwood (1986, p. 238) "cross-cultural comparisons provide a means of deciding which of the psychological constraints on musical scale construction are truly general and which are peculiar to European scale structures." Hence, before we can make any effective generalizations about the processing of specific musical structures, it is imperative that we explore a variety of musical systems.

We decided to begin our study by comparing the processing of the Western major diatonic scale with the Javanese pélog scale by musicians trained within the Western and Javanese musical systems. The Western major diatonic scale is a seven-tone scale formed by intervals or distances consisting of major and minor seconds. The Javanese pélog scale is also a seven-tone scale, however it typically uses intervals or distances that fall between minor and major seconds. Our interest in comparing the processing of these

scales specifically was motivated by a groundbreaking study conducted by Marc Perlman and Carol Krumhansl in 1996. In their study, the authors presented Javanese and Western musicians with a melodic interval magnitude-estimation task. Their subjects were asked to judge the size of various intervals ranging in distance from 60 cents (less than a minor second) to 760 cents (slightly less than a minor sixth). Remarkably, the authors found that when judging interval distances, their subjects used their knowledge of scales and intervals from their respective musical systems as standards for comparison. For instance, the Javanese musicians tended to assimilate the intervals presented to those found in the Javanese pélog scale. The Western musicians tended to assimilate the intervals to those found in the Western equal-tempered scale. In other words, the scales from each culture served as cognitive templates to which the individual intervals presented were compared.

The design for our study was inspired by a previous report by Bischoff Renninger, Granot and Donchin (2003). The authors studied the behavior of the P300 component of the Event-Related Potential (ERP) during musical tasks among groups of musicians trained within the Western musical system. An ERP is a sequence of voltage changes that are time-locked to an eliciting event. The ERP consists of a series of components, each representing neural activity that is triggered in the course of processing an event. ERPs make it possible to monitor, in addition to the subject's overt responses to events, "covert" processes such as the updating of memory and the changing of future strategies. One of the components of the ERP—the P300—has been successfully employed in the study of different aspects of pitch processing (e.g., Besson, Faïta & Requin, 1994; Besson & Macar, 1987; Cohen & Eretz, 1991; Cohen, Granot, Pratt & Barneah, 1993; Crummer, Hantz, Chuang, Walton, & Frisina, 1988; Ford, Roth, & Kopell, 1976; Granot & Donchin, in preparation; Hantz, Crummer, Wayman, Walton, & Frisina, 1992; Hantz, Kreilick, Braveman & Swartz, 1995; Hantz, Kreilick, Kananen & Swartz, 1997; Klein, Coles & Donchin, 1984; Paller, McCarthy & Wood, 1992; Verleger, 1990; Wayman, Frisina, Walton, Hantz & Crummer, 1992). This component was first reported by Sutton and his colleagues (1965) and is characterized by a positive deflection in the waveform with a latency (the time—in milliseconds—elapsing from the onset of the stimulus to the point in time when the component reaches its peak amplitude) of about 300-700 milliseconds. Certain patterns of stimuli are at times more difficult for subjects to process and hence account for longer latency periods.

Many studies investigating pitch processing commonly use the "oddball paradigm" to elicit a P300. In this paradigm, a subject is presented with a sequence of stimuli to which he or she must respond in some way. These stimuli are designated as either "targets" or "standards." The probability of a target stimulus occurring is normally much lower than the probability of a standard stimulus occurring. The ERP elicited under these conditions by the less frequent of the two stimuli (the target) is normally characterized by a large positive-going waveform at a latency of 300-700 milliseconds. According to the "Context Updating" theory of the P300, this component is elicited whenever the circumstances, such as the presentation of a rare or surprising stimulus, require subjects to modify or update their model of an operating context (Donchin, 1981; Donchin & Coles, 1988). For instance, Bischoff Renninger et al. (2003) found that Western musicians with relative pitch abilities elicited a P300 whenever they heard a tone that deviated from, or fell outside of the C-major diatonic scale. In this case the C-major diatonic scale served as the familiar cognitive template, or operating context, for the subjects. Nondiatonic tones, or deviations from the scale template, elicited a P300 because subjects detected a difference between this new stimulus information and the more familiar operating context. Interestingly, in the same study Bischoff Renninger et al. also used subjects with absolute pitch abilities [2] and found that many of these subjects failed to elicit a P300 to the nondiatonic tones. An influential model suggests that absolute pitch musicians, unlike other musicians, do not need to perform this comparison or context updating process when processing auditory stimuli (Klein, Coles & Donchin, 1984).

In the current study, our main research objectives were the following: first, we wanted to ascertain whether in a typical oddball paradigm, non-pélog scale tones would elicit a P300 just as nondiatonic tones had previously in Bischoff Renninger et al. (2003). Second, we were interested to know if musicians who did not have prior experience with the Javanese musical system would even be able to recognize non-pélog scale tones after only brief training, and if so, what types of strategies they would use to do so. Third, if these subjects proved able to distinguish non-pélog scale tones, we were interested in the differences in P300 response to non-pélog scale tones between musicians with and without experience in the Javanese musical system. We hypothesized that although musicians with experience exclusively in the Western system might be able to detect deviations from an unfamiliar musical scale, the amount of prior experience with the scale would nevertheless affect the P300 response to those deviations. In other words, experience

matters, and musicians without experience in the Javanese system might show a smaller P300 due to unfamiliarity with the pélog scale.

METHOD

Ten musically trained subjects, aged 19-39, participated in this study. The experimental group was composed of five (four females, one male) participants in the University of Illinois Javanese Gamelan, who were trained within this musical system. The control group was composed of five (four females, one male) musicians who were not participants in the Gamelan and who had no experience with this musical system. Mean age of the control group was 27.8 (SD = 6.09) and mean age of the experimental group was 24.8 (SD = 8.07). All subjects were drawn from the School of Music at the University of Illinois at Urbana-Champaign.

Each of the subjects sang or played at least one instrument. Mean years of training for the control subject group was 12.6 (SD = 4.56) years and mean years of training for the experimental subject group was 10.8 (SD = 5.40) years. In addition, all subjects had taken at least one college course in aural skills and music theory. The mean number of years the experimental group subjects participated in the UIUC Javanese Gamelan was 1.2 (SD = 1.17). The majority of these subjects had also spent several weeks studying music in Indonesia. Experimental subjects played a variety of Javanese instruments within the UIUC Gamelan. All subjects were first issued an extensive questionnaire in order to obtain more information regarding their musical ability, training, and family background. All subjects were also questioned in a post-experimental debriefing session. At this debriefing session, subjects were asked the following questions:

1. Which of the aural conditions was the most difficult for you?
2. What strategy did you use to effectively complete each of the conditions?

If the subject was from the control group, he or she was questioned about what strategy was used to effectively complete the pélog scale condition.

Stimuli

Subjects were presented with two auditory oddball tasks and one visual oddball task that served as a control. Stimuli for each of the auditory tasks included 300 sine tones generated by a Gateway 386 computer using a program called InstEP. The tones were presented binaurally to the subject via Radio Shack "Pro-90" earphones. The duration of each tone and each stimulus in the visual control condition was 350 milliseconds (including rise/fall times). The time interval between the onset of two successive tones or visual stimuli in the visual condition (ITI) was 1600 milliseconds. The intensity of the tones was 73-75 dBA as measured by a "General Radio 1565B" sound level meter. All overt responses were given with the right and left hand thumbs on a 3-button "Logitech" mouse.

DIATONIC CONDITION

This condition tested the subjects' ability to identify deviations from the C-major diatonic scale. Tones between and including C4 and C5 were presented in three blocks of 100 tones each. The frequencies of these tones were equal to those of the Western equal-tempered scale. Twenty percent of the tones were nondiatonic (falling outside of the C-major diatonic scale), and hence labeled "targets", and eighty percent of the tones were diatonic (falling within the C-major diatonic scale), and hence labeled "standards." The overall task fit the typical oddball format. There were never more than two consecutive nondiatonic tones. Each block began with the C-major triad tones (C, E, G) in order to establish the key and hence establish the subject's cognitive framework for the C-major scale. Subjects were told the identity of these three tones.

Subjects were instructed to press the left button on the mouse if a tone was diatonic, and to press

the right button on the mouse if a tone was nondiatonic. The frequencies for the C-major diatonic tones (standards) were as follows:

1. 262 Hz “C4”
2. 294 Hz “D4”
3. 330 Hz “E4”
4. 349 Hz “F4”
5. 392 Hz “G4”
6. 440 Hz “A4”
7. 494 Hz “B4”

(Use the following links to download the sound files for the seven tones listed above:)

https://kb.osu.edu/dspace/bitstream/1811/24117/1/EMR000015a-262Hz_C4.ogg
https://kb.osu.edu/dspace/bitstream/1811/24117/3/EMR000015a-294Hz_D4.ogg
https://kb.osu.edu/dspace/bitstream/1811/24117/5/EMR000015a-330Hz_E4.ogg
https://kb.osu.edu/dspace/bitstream/1811/24117/6/EMR000015a-349Hz_F4.ogg
https://kb.osu.edu/dspace/bitstream/1811/24117/8/EMR000015a-392Hz_G4.ogg
https://kb.osu.edu/dspace/bitstream/1811/24117/10/EMR000015a-440Hz_A4.ogg
https://kb.osu.edu/dspace/bitstream/1811/24117/12/EMR000015a-494Hz_B4.ogg

The frequencies for the nondiatonic tones (targets) were as follows:

1. 277 Hz “C#4”
2. 311 Hz “D#4”
3. 370 Hz “F#4”
4. 415 Hz “G#4”
5. 466 Hz “A#4”

(Use the following links to download the sound files for the five tones listed above:)

https://kb.osu.edu/dspace/bitstream/1811/24117/2/EMR000015a-277Hz_Cs4.ogg
https://kb.osu.edu/dspace/bitstream/1811/24117/4/EMR000015a-311Hz_Ds4.ogg
https://kb.osu.edu/dspace/bitstream/1811/24117/7/EMR000015a-370Hz_Fs4.ogg
https://kb.osu.edu/dspace/bitstream/1811/24117/9/EMR000015a-415Hz_Gs4.ogg
https://kb.osu.edu/dspace/bitstream/1811/24117/11/EMR000015a-466Hz_As4.ogg

JAVA CONDITION

This condition was similar in structure to the diatonic condition. This condition tested the subjects' ability to identify deviations from the Javanese pélog scale. This scale contains seven tones that are actually divided into the following two sets: a core set of five tones (scale degrees 1, 2, 3, 5, and 6) that are used frequently in Javanese pieces, and a remaining set of non-core tones (scale degrees 4 and 7) rarely used in pieces. Since each Javanese ensemble uses a slightly different tuning for the pélog scale, the scale used in this experiment was identical to the University of Illinois Javanese Gamelan pélog tuning. Tuning was measured with a Seiko ST-747 chromatic tuner during the simultaneous playing of the pélog scale on several of the Gamelan's fixed-pitch instruments (including the sarons, pekings and barungs). Several readings were taken to ensure accuracy. Once these tunings were transferred to the InstEP program, members of the University of Illinois Gamelan were invited to listen to the tones and verify whether they matched the pélog scale used by their ensemble. The measurements obtained for the five core tones of the University of Illinois Gamelan's pélog scale were as follows:

1. 289 Hz
2. 326 Hz
3. 340 Hz
4. 426 Hz
5. 445 Hz

(Use the following links to download the sound files for the five tones listed above:)

https://kb.osu.edu/dspace/bitstream/1811/24117/13/EMR000015a-Pelog1_289Hz.ogg

https://kb.osu.edu/dspace/bitstream/1811/24117/14/EMR000015a-Pelog2_326Hz.ogg

https://kb.osu.edu/dspace/bitstream/1811/24117/15/EMR000015a-Pelog3_340Hz.ogg

https://kb.osu.edu/dspace/bitstream/1811/24117/16/EMR000015a-Pelog5_426Hz.ogg

https://kb.osu.edu/dspace/bitstream/1811/24117/18/EMR000015a-Pelog6_445Hz.ogg

The subject was instructed to click the left mouse button when hearing any of these tones. The measurements for the two non-core tones of the University of Illinois Gamelan's pélog scale were as follows:

1. 400 Hz
2. 504 Hz

(Use the following links to download the sound files for the two tones listed above:)

https://kb.osu.edu/dspace/bitstream/1811/24117/17/EMR000015a-Pelog4_400Hz.ogg

https://kb.osu.edu/dspace/bitstream/1811/24117/19/EMR000015a-Pelog7_504Hz.ogg

The subject was instructed to click the right mouse button when hearing either of these tones. The subject was presented with the five core tones before beginning the task. As in the diatonic condition, the five core tones (standards) were presented eighty percent of the time. The remaining non-core tones, or targets (like the nondiatonic tones in the previous condition) were presented only twenty percent of the time.

VISUAL CONTROL CONDITION

This task served as a control or standard to which the auditory oddballs were compared. The letters "H" and "S" appeared on the computer screen. The subject was again asked to press one button on the mouse if an "S" appeared and another button if "H" appeared. These letters were presented for 350 milliseconds and the inter-stimulus-interval was 1600 milliseconds. The characters subtended a visual angle of 1.3°. The frequency of H:S was 80% to 20%.

DATA ACQUISITION

Data were acquired from each subject in one session of approximately two hours including the time required for filling out forms, application of electrodes, administration of instructions, completion of the task, and debriefing. Subjects sat in a sound attenuating room and were instructed to fixate their eyes on a "+" sign presented on a computer screen located in front of them at an approximate distance of 120 cm. Subjects listened to the tones over Radio Shack "Pro-90" headphones and were instructed to respond as quickly and as accurately as possible. Subjects were told that they would hear a series of tones and that after each tone they would have to make a decision as to whether or not the tone was inside the scale or outside the scale presented before the task at hand. They were informed of the inter-stimulus-interval (ITI) and of the identity of the first three tones in each block, but they were not told anything about the probability of the occurrence of tones.

The Electroencephalogram (EEG) was recorded with silver-silver chloride (Ag-AgCl) electrodes attached to nine scalp sites: Fz, Cz, Pz, F3, C3, P3, F4, C4, P4, and referred to the left mastoid. The electrooculogram (EOG) was recorded from four electrodes placed supraorbitally and laterally around the right eye. Two electrodes were placed above the nasion and served as the grounds. The electrode impedance was kept below 10 kilohms. The EEG and EOG were amplified with Van Gogh model amplifiers with a 10 second time constant and a half amplitude 35 Hz filter. The signals were recorded continuously and digitized every 10 milliseconds. They were stored on zip disks for off line analysis. All overt responses were given with the right and left hand thumbs on a 3-button "Logitech" mouse.

DATA ANALYSIS

The data segments for analysis were extracted from the continuously recorded EEG data. The data was corrected for eye movement artifact using the Eye Movement Correction Procedure (EMCP) (Gratton et al., 1983; Miller et al., 1988). Eye movements that could not be corrected were discarded (resulting in a loss of approximately 15% of trials). The EEG was then digitally filtered from 0-82 Hz using the Cook and Miller (1992) filter. [3] For each of the tasks, the EEG data were averaged separately for the rare and frequent stimuli at the nine electrode sites. The ERPs were then quantified by a base-to-peak amplitude measurement. The baseline was taken as 100 milliseconds prior to stimulus onset. Peaks were measured within a time window corresponding to the P300 (300-800 msec). Each of the data sets was subjected to an ANOVA for the Pz site, which is the site where the P300 component is largest. Results were reported as significant at $p < .05$.

RESULTS

Overt Behavioral Responses

Figures 1 and 2 show the grand averages for the accuracy levels and reaction times for each subject group in each of the three conditions.

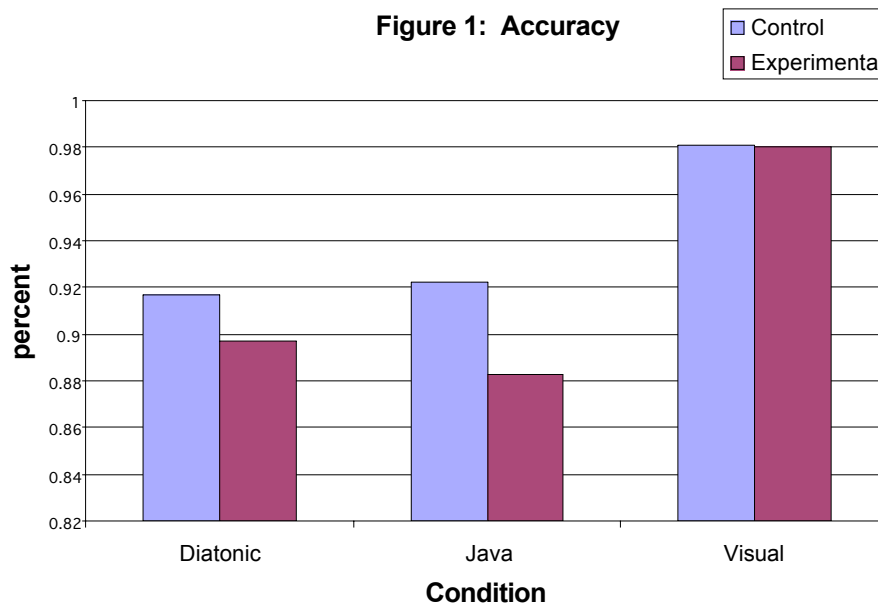


Fig. 1. Grand averages for the accuracy levels for each subject group in each of the three conditions.

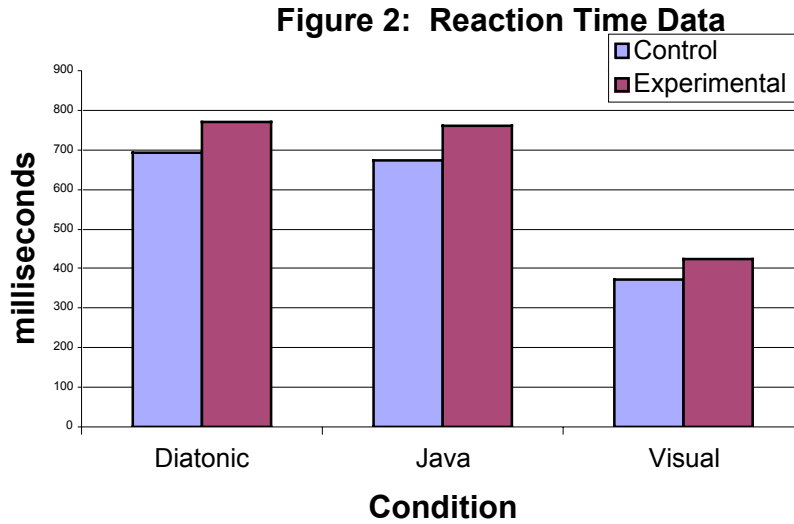


Fig. 2. Grand averages for the reaction times for each subject group in each of the three conditions.

As can be seen from these figures, the control subjects were faster and more accurate than the experimental subjects in all three conditions. All differences were statistically significant between groups except for the difference in visual accuracy. [4]

ERP Results

As seen in Figure 3, both subject groups showed a P300 response to the target events in all conditions.

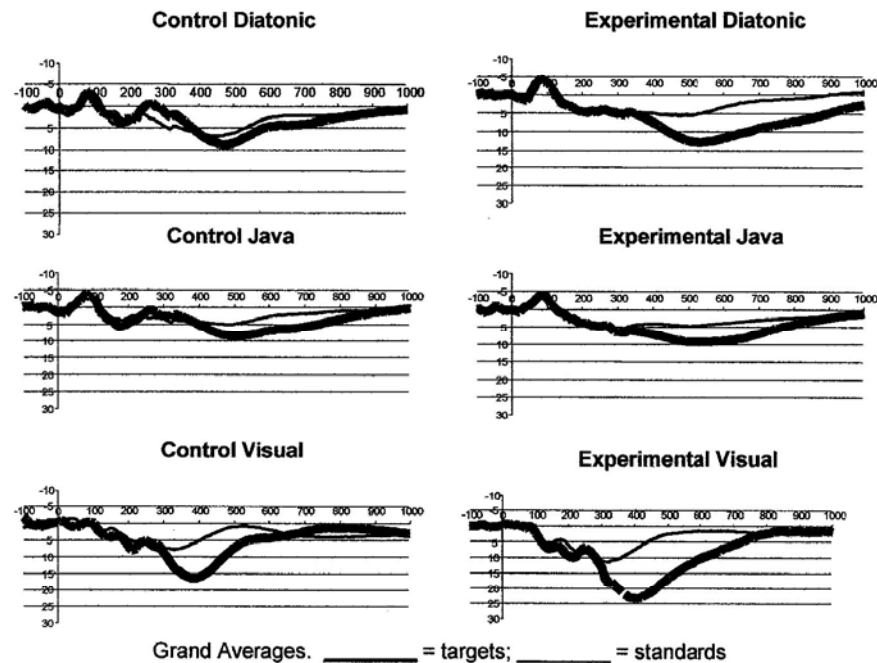


Fig. 3. Both subject groups show a P300 response to the target events in all conditions. Hence, it appears that deviations from the standard or core set of tones in the Javanese pélog scale do elicit a P300, just as

deviations from the C major diatonic scale do (Bischoff Renninger, et al., 2003). Musicians without prior experience with the Javanese system (control subjects) show less of a P300 response to the pélog scale condition. The average P300 amplitude of the control group to the targets in both the diatonic and java conditions respectively is significantly smaller than that of the experimental subjects who have had more experience with the pélog scale, $F(1,100) = 89.641$, $p < .05$, $F(1,100) = 8.08$, $p < .05$.

Hence, it appears that deviations from the standard or core set of tones in the Javanese pélog scale do elicit a P300, just as deviations from the C major diatonic scale do (Bischoff Renninger, et al., 2003). As can also be seen in Figure 3, musicians without prior experience with the Javanese system (the control subjects) showed less of a P300 response to the pélog scale condition. The average P300 amplitude of the control group to the targets in both the diatonic and java conditions respectively was significantly smaller than that of the experimental subjects who had had more experience with the pélog scale, $F(1,100) = 89.641$, $p < .05$, $F(1,100) = 8.08$, $p < .05$. Interestingly, however, the control subjects also showed a significantly faster P300 latency with respect to the auditory conditions, $F(1,2) = .10$, $p < .05$. The slower and less accurate overt responses, as well as the longer P300 latencies of the experimental subjects ran counter to our initial hypotheses. Possible reasons for these data are discussed below.

DISCUSSION

We began this experiment with three key questions: first, whether or not non-pélog scale tones would elicit a P300 just as nondiatonic tones had (Bischoff Renninger, et al., 2003); second, if and how musicians who were not familiar with the Javanese musical system would even be able to recognize non-pélog scale tones after only brief training; and third, if there were differences in the P300 response to non-pélog scale tones between musicians with and without experience in the Javanese musical system. In regards to our first question, deviations from the standard set of tones in a Javanese pélog scale do elicit a P300 just like deviations from the C-major diatonic scale in Bischoff Renninger et al. (2003). In regard to our second question, the post-experimental debriefing session was particularly enlightening. Since our control subjects were unfamiliar with the sound of the pélog scale used in this experiment, many claimed that upon first hearing the scale presented, they simply assimilated the intervals to those in the Western equal-tempered scale similar to the way subjects did in the Perlman and Krumhansl (1996) study. In order to determine deviations from the pélog scale, they also focused on cues such as pitch height. For instance, many control subjects remarked that the 504 Hz non-standard tone (seventh scale degree) of the pélog scale sounded “too high” to fit into the group of core pélog tones. Many even claimed that this listening strategy made the Java condition easier than the diatonic condition. They also claimed that the fewer non-standard scale tones in the Java condition compared to the nondiatonic condition made the Java condition easier. The experimental subjects, on the other hand, claimed that the Java condition was difficult for them, not because they were unfamiliar with the interval relationships of the scale, but because the timbral cues were missing from the sine tones. They had become accustomed to hearing the overtones from the various instruments in the gamelan and they claimed that these cues always helped them to detect scalar deviations. Hence, another reason for their slower responses may be that they compared the sine tones they heard in the experiment to their internal framework of the pélog scale. When these frameworks did not exactly correspond due to the lack of timbral cues, their processing time was delayed.

In regards to our third question, prior experience does seem to matter. Even after training, musicians without prior experience in the Javanese system show a smaller P300 response to the pélog scale. However, it was still puzzling why the control subjects collectively showed a smaller P300 response when both the latency and overt response data indicated that they were faster and more accurate than the experimental group in every condition. In order to explore this further, we decided to take closer look at the individual subject data (see Figures 4 and 5).

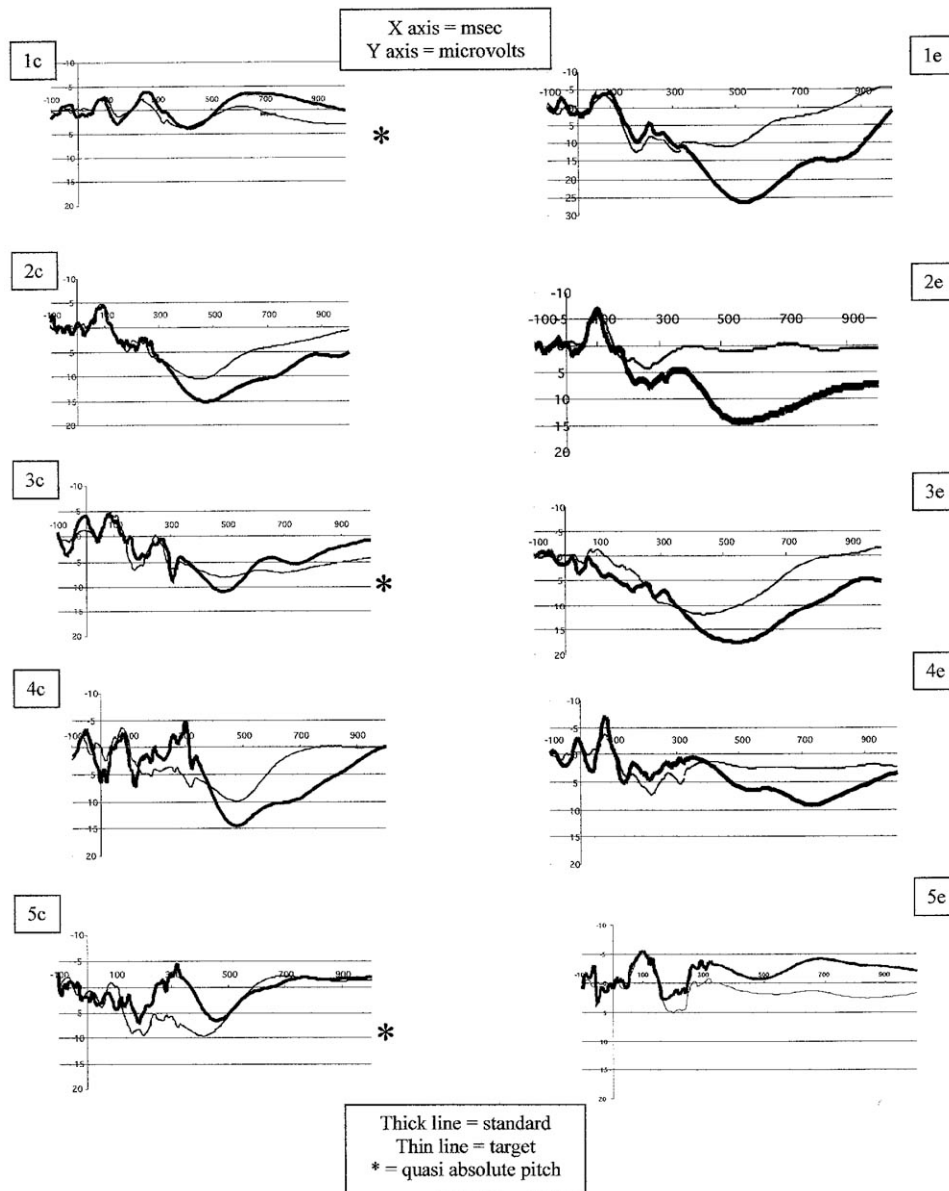


Fig. 4. Individual Subject Data – Diatonic Condition.

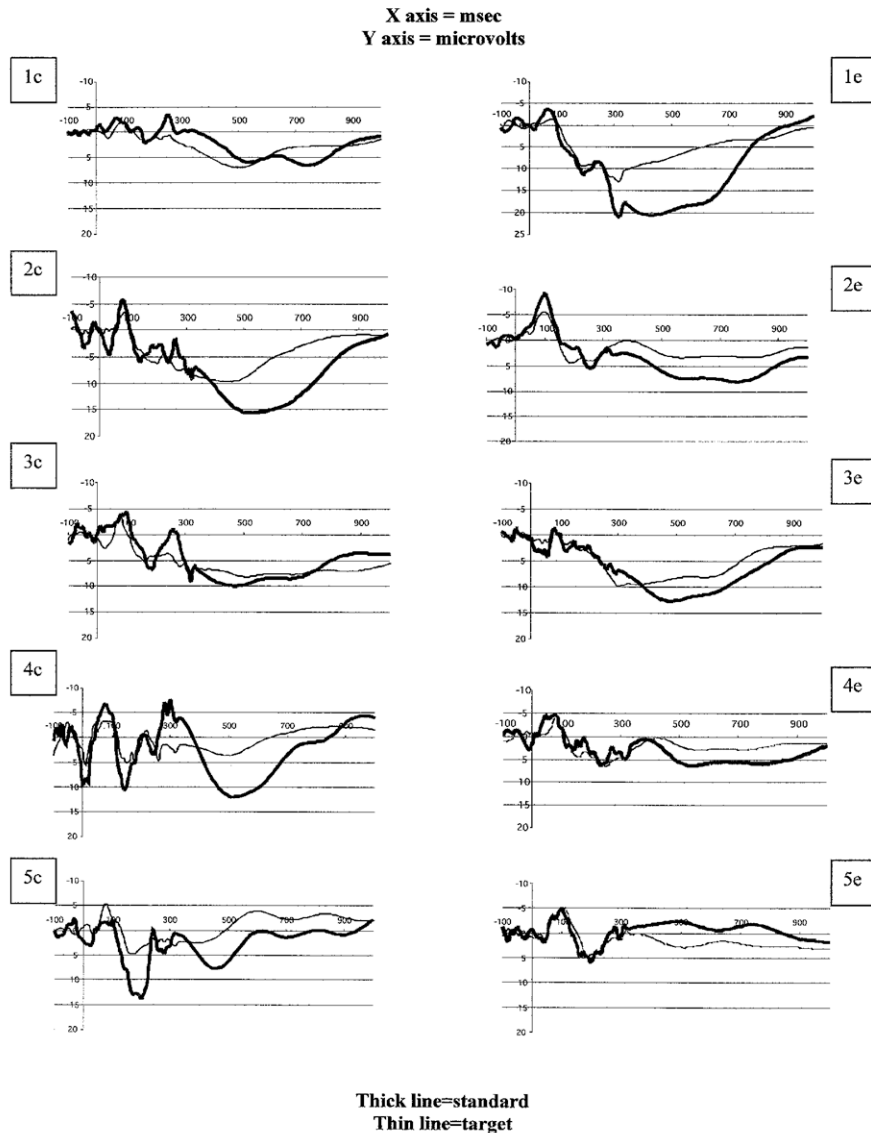


Fig. 5. Individual Subject Data – Java Condition

Grand averages often hide individual processes, so an analysis of each subject's data has proven to be a useful tool, especially in P300 research (Klein et al., 1984; Bischoff Renninger et al., 2003). A closer look at the initial subject surveys revealed that although none of the subjects were tested for absolute pitch, the pitch naming abilities of the control subjects were very acute. For example, subject 3c claimed that she can "often identify and produce the pitches of middle-C (C4), A4 and Bb4." However, her ability is weakened when the pitches are very high or very low. Subject 1c claimed that he can "sometimes produce an E or an F above middle C (E5 and F5)," and subject 5c claimed that she can "sometimes produce a middle-C (C4) or a G below middle C (G3)." These characteristics are all indications of possible quasi-absolute pitch abilities [5] in these subjects. These subjects individually showed reduced P300s (see Figure 4). This finding correlates with several studies that have indicated a reduced P300 component in absolute pitch subjects during aural tasks (Klein et al., 1984; Hantz et al., 1992; Wayman et al., 1992; Crummer et al., 1994; Bischoff Renninger et al., 1995 -- unpublished data; Johnston, 1994; Hantz et al., 1992; Wayman et al., 1992; Crummer et al., 1994; Bischoff Renninger et al., 2003). This may explain why the grand average of the P300 in the control group was smaller than the grand average of the P300 in the

experimental group, even though the control subjects performed better overtly.

CONCLUSION

In summary, our study has yielded several interesting findings. First, our results demonstrate that responses to scalar deviations found in earlier experiments do appear, at least so far, to carry over to non-Western musical systems. Current results also corroborate earlier evidence by Perlman and Krumhansl (1996) that suggest listeners assimilate intervals in unfamiliar scales to a familiar internal scalar context. We believe that this assimilation process was one of the primary reasons our subjects responded to the same tones in very different ways. Finally, we have found that a closer look at individual ERP data, as well as reaction time and accuracy data, has helped shed greater light on processing strategies. For instance, subjects with evidence of quasi-absolute pitch abilities showed smaller P300 amplitudes to the target tones. Their responses certainly had an effect on the control group grand average and helped to clarify some of the results.

Overall, ERPs have proven to be a highly useful tool in testing models of information processing within the context of music perception. It is indeed our hope that more extensive ERP studies of non-Western musical systems will be forthcoming.

NOTES

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[2] Absolute Pitch is generally defined as the ability to name and/or produce a pitch without being provided with a reference pitch.

[3] There is considerable evidence that the P300 resides at the low end of the spectrum (see, e.g., Duncan-Johnson & Donchin, 1977). They report substantial effects on P300 amplitude when there is a change in the low pass from 0.01 to 0.1, but little effect of expanding the high pass beyond 8-10 Hz. Our specific choice of bandwidth reflected our interest in the P300 and our preference to avoid contamination of the results by alpha activity and other sources of noise.

[4] Statistics for the overt behavioral responses: Diatonic Accuracy: $F(1,8) = 0.193$, $p < .05$; Java Accuracy: $F(1,8) = 0.774$, $p < .05$; Visual Accuracy: $F(1,8) = 0.002$, $p < .05$; Diatonic Reaction Time: $F(1,8) = 1.108$, $p < .05$; Java Reaction Time: $F(1,8) = 2.274$, $p < .05$; Visual Reaction Time: $F(1,8) = 2.705$, $p < .05$.

[5] Quasi-Absolute Pitch means that subjects can identify one or two pitches (usually A=440 Hz or middle C) and then relate others to them (Bachem, 1955).

REFERENCES

- Bachem, A. (1955). Absolute pitch. *Journal of the Acoustical Society of America*, Vol. 27, pp. 1180-1185.
- Besson, M., Faïta, F., & Requin, J. (1994). Brain waves associated with musical incongruities differ for musicians and non-musicians. *Neuroscience Letters*, Vol. 168, pp. 101-105.
- Besson, M., & Macar, F. (1987). An event-related potential analysis of incongruity in music and other non-linguistic contexts. *Psychophysiology*, Vol. 24, pp. 14-25.

- Bischoff Renninger, L.A., Granot, R., & Donchin, E. (2003). Absolute pitch and the P300 component of the event-related potential: An exploration of variables that may account for individual differences. *Music Perception*, Vol. 20, No. 4, pp. 357-382.
- Cohen, D., & Erez, A. (1991). Event-related potential measurements of cognitive components in response to pitch patterns. *Music Perception*, Vol. 8, pp. 405-430.
- Cohen, D., Granot, R., Pratt, H., & Barneah, A. (1993). Cognitive meanings of musical elements as disclosed by event-related potential (ERP) and verbal experiments. *Music Perception*, Vol. 11, No. 2, pp. 153-184.
- Cook, E.W., & Miller, G. (1992). Digital filtering: Background and tutorial for psychophysicists. *Psychophysiology*, Vol. 29, No. 3, pp. 350-367.
- Crummer, G.C., Walton, J.P., Wayman, J., Hantz, E.C., & Frisina, R.D. (1994). Neural processing of musical timbre by musicians, nonmusicians, and musicians possessing absolute pitch. *Journal of the Acoustical Society of America*, Vol. 95, No. 5, pp. 2720-2727.
- Donchin, E. (1981). Surprise! . . . Surprise? *Psychophysiology*, Vol. 18, No. 5, pp. 493-513.
- Donchin, E., & Coles, M. G. H. (1988). Precommentary: Is the P300 Component a manifestation of context updating? *Behavioral and Brain Sciences*, Vol. 11, No. 3, pp. 357-374.
- Dowling, W. J. (1978). Scale and contour: Two components of a theory of memory for melodies. *Psychological Review*, Vol. 85, pp. 341-354.
- Dowling, W. J., & Harwood, D. L. (1986). *Music Cognition*. Orlando: Academic Press, Inc.
- Ford, J., Roth, W., & Kopell, B. (1976). Auditory evoked potentials to unpredictable shifts in pitch. *Psychophysiology*, Vol. 13, No. 1, pp. 32-39.
- Gratton, G., Coles, M.G.H., & Donchin, E. (1983). A new method for off-line removal of ocular artifact. *Electroencephalography and Clinical Neurophysiology*, Vol. 55, pp. 468-484.
- Hantz, E.C., Crummer, G.C., Wayman, J.W., Walton, J.P., & Frisina, R.D. (1992). Effects of musical training and absolute pitch on the neural processing of melodic intervals: A P3 event-related potential study. *Music Perception*, Vol. 10, No. 1, pp. 25-42.
- Hantz, E.C., Kreilick, K.G., Braveman, A.L., & Swartz, Kenneth P. (1995). Effects of musical training and absolute pitch on a pitch memory task: An event-related potential study. *Psychomusicology*, Vol. 14, pp. 53-76.
- Hantz, E.C., Kreilick, K.G., Kananen, W., & Swartz, K.P. (1997). Neural responses to melodic and harmonic closure: An event-related-potential study. *Music Perception*, Vol. 15, No. 1, pp. 69-98.
- Klein, M., Coles, M.G.H., & Donchin, E. (1984). People with absolute pitch process tones without producing a P300. *Science*, Vol. 223, pp. 1306-1309.
- Krumhansl, C. L. (1990). *Cognitive Foundations of Musical Pitch*. New York: Oxford University Press.
- Paller, K.A., McCarthy, G., & Wood, C.C. (1992). Event-related potentials elicited by deviant endings to melodies. *Psychophysiology*, Vol. 29, No. 2, pp. 202-206.
- Perlman, M., & Krumhansl, C. (1996). An experimental study of internal interval standards in Javanese and Western musicians. *Music Perception*, Vol. 14, No. 2, pp. 95-116.

Sutton, S., Tueting, P., Zubin, J., & John, E.R. (1965). Information delivery and the sensory evoked potential. *Science*, Vol. 155, pp. 1436-1439.

Takeuchi, A.H., & Hulse, S.H. (1993). Absolute pitch. *Psychological Bulletin*, Vol. 113, No. 2, pp. 345-361.

Wayman, J.W., Frisina, R.D., Walton, J.P., Hantz, E.C. & Crummer, G.C. (1992). Effects of musical training and absolute pitch ability on event-Related activity in response to sine tones. *Journal of the Acoustical Society of America*, Vol. 91, No. 6, pp. 3527-3531.